CHAPTER 2

AMPHIBIANS & REPTILES

EFFECTS OF RECREATION ON ROCKY MOUNTAIN WILDLIFE
A Review for Montana

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MONTANA CHAPTER OF THE WILDLIFE SOCIETY

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ABSTRACT

Through their interactions with other organisms, amphibians and reptiles are key components of many ecological systems. Consistent with the overall decline in biodiversity, amphibian and reptile populations have recently, or are currently, experiencing declines worldwide and in Montana. Direct and indirect impacts from human recreational activities may contribute to these declines. Although recreational impacts on Montana's herpetofauna have been little studied, the scientific literature provides several examples of factors often associated with recreation that do affect amphibian and reptile populations. Nonindigenous species can directly affect herpetofauna via competition and predation, and can indirectly affect herpetofauna through their management. For example, introduced fishes and bullfrogs may prey on or out compete native amphibians and reptiles and piscicides, herbicides, and pesticides used to control nonindigenous species are known to negatively impact populations of herpetofauna. Road traffic and off road vehicle use directly kill herpetofauna and indirectly impact populations by creating migration barriers, destroying habitats, and increasing sedimentation and chemical contamination. The development of recreational facilities and water impoundments may result in the loss of key breeding, foraging, and overwintering habitats for herpetofauna. Harvesting and collecting can have extremely negative impacts on herpetofauna populations and the general loss of habitat may lead to fragmentation and disruption of metapopulation dynamics. The relatively poor knowledge we have of the distribution, biology, and status of many of Montana's herpetofauna highlights the need to undertake thorough inventories of our public lands. Furthermore, the lack of knowledge of the distribution and status of many of these species makes it all the more important to properly manage recreational and travel activities that may negatively impact them.

INTRODUCTION

Importance

Montana's 13 native amphibians and 17 native reptiles represent a valuable biological and cultural resource whose conservation is essential not only to their own survival, but to the survival of other vertebrate and invertebrate taxa as well. As larvae, amphibians structure aquatic communities by being important herbivores (e.g., Dickman 1968 and Seale 1980), competitors (e.g., Werner 1992), predators (e.g., Morin 1983 and Wilbur et al. 1983), and prey (e.g., Wilbur 1997). Many reptiles and metamorphosing amphibians act as key links between aquatic and terrestrial food webs as they transfer energy from aquatic prey to terrestrial predators (Wilbur 1997). The importance of adult amphibians and reptiles in terrestrial food webs is highlighted by their efficiency at converting the prey they consume to new animal tissue; as ectotherms they are more than 25 times more efficient than mammals or birds (Pough 1980, 1983). Their importance to terrestrial food webs is further highlighted by studies conducted in eastern deciduous forests and western deserts which demonstrate that amphibians and reptiles in those respective communities rival or exceed mammals and birds with respect to numbers, biomass, and energetics (Burton and Likens 1975*a*, Burton and Likens 1975*b,* and Turner et al. 1976).

Amphibians and reptiles also contribute a great deal to human welfare. In many impoverished societies they are among the most important sources of animal protein and many affluent societies import large quantities of frog legs for culinary purposes; the U.S. imports 1,000-2,000 tons of frog legs annually, while France imports 3.4 million tons annually (Stebbins and Cohen 1995). Amphibians and reptiles have been extremely important to studies of vertebrate anatomy, neurology, physiology, embryology, developmental biology, genetics, evolutionary biology, animal behavior, and community ecology (Stebbins and Cohen 1995, Petranka 1998, and Pough et al. 1998). Amphibian eggs and larvae have been extensively used in toxicological studies on the effects of chemical contaminants that may impact human health (Harfenist et al. 1989). Skin secretions of some amphibians show promise as antibiotics and as nonaddictive pain killers that are 200 times more powerful than morphine (Stebbins and Cohen 1995). The venoms of many snakes are being used to fight metastasizing cancers (Trikha et al. 1994), prevent thromboses that cause heart attacks and strokes (Lathan et al. 1996), and help understand diseases such as lupus (Court 1997). Amphibians are important in the control of insect pests such as mosquitoes, and many snakes control rodents that threaten crop damage (Pough et al. 1998). Amphibians and reptiles are also important reminders of some of the most significant events in the evolution of vertebrate life, the movement into the terrestrial environment by amphibians some 360 million years ago and the gaining of independence from aquatic environments by reptiles some 260 million years ago (Pough et al. 1998). Finally, some amphibians and reptiles are valuable bioindicators of environmental health because amphibians have highly permeable skin and egg membranes and complex life cycles with aquatic and terrestrial life history stages and both amphibians and reptiles are often philopatric to specific breeding, foraging, and overwintering habitats connected by habitats suitable for migration (Turner 1957, Bauerle et al. 1975, Duellman and Trueb 1986, Weygoldt 1989, Wake 1991, Olson 1992, Blaustein 1993, 1994, and Welsh and Ollivier 1998).

Status

In the past few hundred years, increases in human population and our ability to impact natural ecosystems have led to a dramatic increase in the global rate of species extinction (Wilson and Peter 1988). Within this overall biodiversity crisis, evidence has accumulated during the past few decades that amphibians around the globe may be declining at a higher rate than other taxonomic groups (Blaustein and Wake 1990, Phillips 1990, Wyman 1990, Wake and Morowitz 1991, Drost and Fellers 1996, but see Pechmann and Wilbur 1994). In North America, amphibian declines have been most numerous in the West and have occurred among species that occupy a variety of elevations, habitat types, and disturbance regimes (Corn 1994). Many reptiles have also declined (e.g., Dodd 1988, Garber and Burger 1995, Grover and DeFalco 1995, and Greene 1997), but these declines have not generated as much public or scientific interest.

Seven major factors, and their interaction, have been implicated as causative agents of amphibian declines. These include: (1) loss, deterioration, and fragmentation of aquatic and terrestrial habitats (e.g., Bury et al. 1980, Schwalbe 1993, Van Rooy and Stumpel 1995, Lind et al. 1996, and Beebee 1997); (2) introduction of nonindigenous species (e.g., Bradford 1989, Fisher and Schaffer 1996, Gamradt and Kats 1996, Kupferberg 1996, Adams 1997, Hecnar and M`Closkey 1997, and Kiesecker and Blaustein 1997*a*); (3) environmental pollutants (e.g., Lewis et al. 1985, Kirk

1988, Beebee et al. 1990, and Dunson et al. 1992); (4) increased ambient UV-B radiation (e.g., Blaustein et al. 1994a, Blaustein et al. 1995, Kiesecker and Blaustein 1995, and Nagl and Hofer 1997); (5) climate change (e.g., Pounds and Crump 1994, Stewart 1995, and Pounds et al. 1999); (6) pathogens (e.g., Carey 1993, Kiesecker and Blaustein 1997*b*, Berger et al. 1998, and Lips 1999); and (7) human commerce (e.g. Nace and Rosen 1979, Jennings and Hayes 1985, Buck 1997, and Pough et al. 1998). Not suprisingly, a majority of these factors have also been implicated as causative agents of reptile declines and the overall decline in biodiversity (e.g., Dodd 1988, Wilson and Peters 1988, Henderson 1992, Weir 1992, Guillete et al. 1994, Ballinger and Watts 1995, and Wilkinson 1996*b*). Thus, the conspicuous decline of amphibian populations may indeed be a good indication of the declining health of our environment.

The most up-to-date Montana Natural Heritage Program, U.S. Forest Service, Bureau of Land Management and Montana Fish, Wildlife, and Parks status ranks for Montana's amphibians and reptiles are shown in Appendix B; no herpetofauna in Montana have been or are being considered for listing under the federal Endangered Species Act. Unfortunately, for most herpetofauna in Montana, the status ranks in Appendix B are largely a result of guesswork because we lack baseline data that would allow us to properly evaluate the current status and trends of populations. However, there is evidence that at least 3 species, the northern leopard frog (*Rana pipiens*), the boreal toad (*Bufo boreas boreas*), and the common garter snake (*Thamnophis sirtalis*), have undergone or may currently be undergoing declines. As has happened in many other western states and Canadian provinces, the northern leopard frog has become extinct throughout nearly all of its former range in western Montana and has apparently been extirpated from 80% of historic localities on the northwestern plains (Reichel and Flath 1995, Stebbins and Cohen 1995, and Koch et al. 1996). Although still widespread across the contiguous mountainous regions of Montana, recent surveys have failed to find boreal toads at most historical sites, have found them at less than 10% of sites with suitable habitat, and have found some evidence that breeding is being restricted to lower elevations (Maxell et al. 1998). These findings are of particular concern in light of declines in toad populations across a number of western states (Corn et al. 1989 and Stebbins and Cohen 1995). The common garter snake's range extends across the entire state, but it has rarely been encountered in recent surveys on the eastern plains (Reichel 1995, Hendricks and Reichel 1996, Rauscher 1998, and Roedel and Hendricks 1998). Furthermore, although there are problems associated with using ratios of species encountered to determine a species' status, the current ratio of 1 common garter snake encountered for every 10-15 western terrestrial garter snakes (*Thamnophis elegans*) may be indicative of declines in common garter snakes in western Montana when compared with historical reports that they were encountered as frequently as the western terrestrial garter snake (Koch et al. 1996, and Bryce Maxell, personal observation).

In addition to these species, there should be concern about the status of a number of others, including the plains spadefoot (*Scaphiopus bombifrons*), Great Plains toad (*Bufo cognatus*), Canadian toad (*Bufo hemiophrys*), snapping turtle (*Chelydra serpentina*), spiny softshell (*Apalone spinifera*), short-horned lizard (*Phrynosoma hernandezi*), sagebrush lizard (*Sceloporus graciosus*), western skink (*Eumeces skiltonianus*), western hognose snake (*Heterodon nasicus*), smooth green snake (*Opheodrys vernalis*), and milk snake (*Lampropeltis triangulum*). There are relatively few historic records for these species and recent surveys either failed to detect them in a number of areas or were unlikely to detect them given the cryptic nature of the species and the limitations of the survey methods used (e.g. Reichel 1995, Hendricks and Reichel 1996, Rauscher 1998, and Roedel and Hendricks 1998). It is quite possible that a number of these species could be extirpated from a part of their range or even go extinct across the state without anyone being aware of it due to the poor knowledge of the species' distributions and their responses to anthropogenic impacts. This point is highlighted by the findings of Hart et al. (1998) and Redmond et al. (1998) who recently determined that 60-70% of the predicted ranges of these species are in private lands without any formal protection from conversion of natural habitat types to anthropogenic habitat types. Finally, our lack of knowledge about the status of Montana's herpetofauna may be best illustrated by the fact that it is possible that 4 additional species, the Idaho giant salamander (*Dicamptodon aterrimus*), Great Basin spadefoot (*Scaphiopus intermontanus*), wood frog (*Rana sylvatica*), and pygmy short-horned lizard (*Phrynosoma douglasi*), are present in the state, but have yet to be properly documented as a result of the paucity of survey work that has been done (Maxell, In Press).

Issues of Concern

Montana's 13 native amphibians and 17 native reptiles occupy a diverse array of habitats and vary greatly in their life history patterns (Reichel and Flath 1995, and Hart et al. 1998). Furthermore, relatively few studies have

investigated the impacts of human recreation and travel activities on herpetofauna. Thus, identification of all possible impacts of recreation and travel activities on herpetofauna, and development of a comprehensive set of guidelines that would mitigate these impacts, are not possible at this time. However, a review of the scientific literature has allowed us to identify: (1) recreational and travel activities that are most likely to impact Montana's herpetofauna; (2) key characteristics of the biology of herpetofauna that need to be addressed in order to minimize the impacts of these activities; (3) a general set of guidelines that would allow human recreational and travel impacts to be minimized; and (4) major habitat types and associated species that should be addressed by resource managers.

Possibly the most important feature of the biology of amphibians and reptiles that management plans need to address is their use of habitats and the migrations they undergo in order to use them. At higher latitudes all herpetofauna require suitable breeding/rearing, foraging and overwintering habitats in order to survive (e.g., Turner 1957, Dole 1965, Ewert 1969, McAuliffe 1978, and King 1990). Many amphibians require warmer lentic waters with aquatic vegetation for breeding/rearing habitat, riparian areas that support large insect populations for foraging habitat, and terrestrial burrows, forest litter, or deep waters that are unlikely to freeze for overwintering habitats (Nussbaum et al. 1983, and Stebbins and Cohen 1995). Many reptiles require habitats with adequate sun exposure and substrates appropriate for nesting or maternal basking, habitats that support insect, fish, amphibian, mammal, or bird populations for foraging, and deep aquatic habitats with mud bottoms or deep rock crevices or mammal burrows that are unlikely to freeze for overwintering (Pough et al. 1998). Loss or exclusion from any one of these habitats, or loss of the resources they contain, may cause the species to decline or be extirpated from a local area unless individuals dispersing from nearby areas recolonize (e.g., Hecnar and M`Closkey 1996, and Patla 1997). In cases where all 3 of these habitats are present in a relatively small geographic area herpetofauna often do not undergo extensive migrations between overwintering, breeding, and foraging habitats (Sinsch 1990). In these instances, isolated populations may successfully perpetuate themselves unless the specific area is altered by natural succession or anthropogenic activity (e.g., Gulve 1994). In cases where the 3 required habitat types are isolated spatially, herpetofauna are capable of undertaking quite extensive seasonal migrations (e.g., Gregory and Stewart 1975, King 1990, Sinsch 1990, and Dodd 1996). In these instances, they are not only dependent on suitable breeding, foraging and overwintering habitats, but are also dependent on habitats suitable for migration (Dodd and Cade 1998). Coupled with the importance of considering all habitat requirements is the importance of considering the extreme philopatry shown by many herpetofauna species to the same breeding, foraging and overwintering sites year after year (Daugherty and Sheldon 1982, Sinsch 1990, Stebbins and Cohen 1995, and Pough et al. 1998). Thus, if these habitats are lost due to succession or anthropogenic alteration, or if individuals' abilities to migrate between them are hindered as a result of anthropogenic alteration of habitat then the species may be extirpated from an area.

The specific habitat requirements and predicted distributions of Montana's amphibians and reptiles were recently reviewed in the Montana Atlas of Terrestrial Vertebrates (Hart et al. 1998). This document summarizes the ranges, describes the habitat requirements of each life history stage, provides a list of key references on habitat use, and models predicted distributions for each species. The Montana Gap Analysis Final Report (Redmond et al. 1998) recently summarized species richness for amphibians and reptiles across the state and identified the proportion of lands under a variety of land stewardship regimes for each species individually and for amphibians and reptiles as entire taxonomic groups. In addition, Maxell et al. (In Review) reviewed the history of the study of herpetology in Montana, reviewed the status of Montana's herpetofauna, gave a list of all known museum records, gave dot-distribution maps for museum and observation records, and compiled an indexed bibliography of all known published and gray literature on Montana's herpetofauna. Together these reports provide the most up-to-date and comprehensive understanding of the distribution, status, and habitat use of Montana's herpetofauna and should be used by state and federal agencies, tribal governments, and private individuals in the direct development of large-scale management plans and as a reference when making smaller-scale management decisions. As a supplement to the information supplied in these reports, and for the reader's reference, we have summarized major habitat types and the amphibians and reptiles associated with each in Table 2.1.

A review of the scientific literature identified six major themes that encompass the major impacts that recreation and travel activities are likely to have on Montana's herpetofauna. They are:

1. Nonindigenous species and their management
2. Road and trail development and on- and off-road vehicle use
3. Development and management of recreational facilities and water impounds
4. Harvest and commerce

5. Habitat fragmentation and metapopulation impacts
6. Lack of information / research needs

Specific areas of concern associated with each of these themes and a general set of management guidelines that would allow human recreational and travel impacts to be minimized are addressed individually in the remainder of the chapter.

NONINDIGENOUS SPECIES AND THEIR MANAGEMENT

Background

During the last 10-20,000 years humans have both knowingly and unwittingly increased the rate of invasions of nonindigenous species to the extent that they are now, and will continue to be, one of the leading threats to biological diversity around the globe (Elton 1958 and Soulé 1990). The most successful invaders have been species that are commensals with humans through their use as food, shelter, sport, or biotic control and they have been most successful at invading early successional or disturbed habitats (MacAthur and Wilson 1967 and Lodge 1993). Unfortunately, many of our attempts to control these nonindigenous species have further harmed our native species (e.g. Pimental 1971, Kirk 1988, and Fontenot et al. 1994). In Montana, the introduction of nonindigenous fish, bullfrogs, weeds, and pathogens, and attempts to remove or control nonindigenous fish and weeds may be one of the most important categories of threat to the native herpetofauna.

Impacts of Nonindigenous Fish

At least 52 species of fish belonging to 14 families have been introduced in Montana (Nico and Fuller 1999 and Fuller et al. 1999). Of these species, 9 belonging to 3 families have been widely introduced for recreational fishing and have been implicated in the decline of native amphibians across the globe (Sexton and Phillips 1986, Bahls 1992, Bradford et al. 1993, Bronmark and Endenhamn 1994, Brana et al. 1996, Hecnar and M`Closkey 1997a, and Fuller et al. 1999). These species include pumpkinseed (*Lepomis gibbosus*), blue gill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieu*) in the family Centrarchidae, yellow perch (*Perca flavescens*) in the family Percidae, and rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarki*), brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) in the family Salmonidae. Introductions of warm water centrarchids and percids and cold water salmonids have undoubtedly been made into a number of low-elevation water bodies that support or formerly supported amphibian communities. However, introductions of salmonids at higher elevations, which began as early as the 1880s (Jordan 1891), are likely to have had a particularly important impact on native amphibian communities inhabiting high (>800 meters) mountain lakes because 95% of these lakes in the western United States were naturally fishless prior to stocking (Bahls 1992). Thus, historically, as many as 15,000 lakes at elevations greater than 800 meters in the western United States may have supported native amphibian communities without the threat of predation or competition from fish. Presently, about 9,500 of the West's high-elevation lakes and virtually all of the deeper lakes contain introduced salmonids (Bahls 1992). In Montana, approximately 47% of the state's 1,650 high-elevation lakes now contain nonindigenous salmonids (Bahls 1992).

Egg, larval, and adult amphibians may be subject to direct predation by introduced warm and cold water fishes (e.g.s, Korschgen and Baskett 1963, Licht 1969, Semlitsch and Gibbons 1988, and Liss and Larson 1991). Similarly, all 3 amphibian life history stages are likely to be indirectly effected by the threat of predation due to (1) adult avoidance of oviposition sites where predators are present (e.g. Resetarits and Wilbur 1989 and Hopey and Petranka 1994), (2) decreased larval foraging and, therefore, growth rates as a result of staying in refuges to avoid predators (e.g., Figiel and Semlitsch 1990, Skelly 1992, Kiesecker and Blaustein 1998, and Tyler et al. 1998b), and (3) decreased adult foraging, growth rates, and overwinter survival as a result of avoiding areas with fishes (e.g., Bradford 1983).
Reptiles, particularly younger age classes, are likely to be directly preyed on by nonindigenous fish (Bryce Maxell, personal observation) and are also likely to be negatively effected indirectly as a result of the loss of amphibians, which they depend on as prey (e.g., Jennings et al. 1992 and Koch et al. 1996).

Impacts of Chemical Management of Sport Fisheries

Rotenone and commercial piscicides containing rotenone have often been used to remove unwanted fish stocks from a variety of aquatic habitats (Schnick 1974). The impacts of rotenone-containing piscicides on amphibians and turtles were recently reviewed by Fontenot et al. (1994) and McCoid and Bettoli (1996). They found the range of lethal doses of rotenone-containing piscicides for amphibian larvae and turtles (0.1-0.580 mg/L) to overlap to a large extent with lethal doses for fish (0.0165-0.665 mg/L), and to be much lower than the concentrations commonly used in fisheries management (0.5-3.0 mg/L). Furthermore, they reviewed, a number of studies that noted substantial mortality of nontarget turtles and amphibian larvae. However, the effects of rotenone on turtles and newly metamorphosed and adult amphibians was found to vary with the degree of each species' aquatic respiration and their likelihood of exiting treated water bodies (Fontenot et al. 1994 and McCoid and Bettoli 1996). Nontarget mortality of amphibian larvae was reduced by Hockin et al. (1985) by providing several untreated refuge areas that could be accessed through Netlon fence divisions and by protecting one refuge area containing high densities of amphibian larvae by placing a sheet of hessian sacking soaked in a saturated potassium permanganate solution that neutralized the rotenone. The nontarget effects of another piscicide, antimycin, have apparently not been formally studied, but preliminary observations seem to indicate that antimycin is also toxic to turtles and amphibian larvae (Patla 1998). In Montana all amphibian larvae as well as tailed frog (*Ascaphus truei*) adults and highly aquatic spiny softshells and snapping turtles either use some sort of aquatic respiration or may be unlikely to exit treated water bodies depending on the time of day and presence/absence of humans (Daugherty and Sheldon 1982 and Ernst et al. 1994). Thus, all of these species are likely to suffer mortality through the application of piscicides.

Impacts of Nonindigenous Bullfrogs

Bullfrogs (*Rana catesbeiana*) are native to the United States east of a line extending from northwest Wisconsin to south central Texas (Bury and Whelan 1984). However, they have now been widely introduced into permanent waters in all lower forty-eight states, with the possible exception of North Dakota, and have been implicated in the declines of a number of amphibian and reptile species throughout this area (Moyle 1973, Hammerson 1982, Bury and Whelan 1984, Kupferberg 1994, Rosen et al. 1995, Kupferberg 1997, and Lawler et al. 1999). The impetus for bullfrog introduction seems largely to be due to their use as a recreational hunting and food item, apparently, in some cases, as a result of native frogs having already declined because of human hunting and consumption (Bury and Whelan 1984 and Jennings and Hayes 1985). In Montana, bullfrogs were introduced for unknown reasons into the Bitterroot Valley sometime prior to 1968 and more than 20 distinct populations have now been reported along the Bitterroot, Flathead and Clark Fork Rivers and at a few other isolated localities around the state (Black 1969*a*, 1969*b*, Werner and Reichel 1994, Reichel 1995, Hendricks and Reichel 1996, Werner et al. 1998, and Maxell, In Press). Unfortunately, bullfrogs continue to be introduced into new sites from source populations both inside and outside of Montana despite the fact that unauthorized introduction or transplantation of wildlife into the natural environment is prohibited by Montana law (Bryce Maxell, personal observation and Levell 1995; MCA 87-5-711). The Montana state legislature could further prohibit the introduction of bullfrogs by designating them a species that is detrimental to Montana's native flora and fauna (Levell 1995; MCA 87-5-712).

All 3 life history stages of amphibians, as well as smaller aquatic reptiles, may be subject to direct predation by adult bullfrogs (e.g.s, Korschgen and Baskett 1963, Carpenter and Morrison 1973, Bury and Whelan 1984, and Clarkson and DeVos 1986). Additionally, both the eggs and larvae of native amphibians may be preyed upon by larval bullfrogs (e.g., Ehrlich 1979 and Kiesecker and Blaustein 1997*b*). Furthermore, egg, larval and adult amphibians are also likely to be indirectly effected by the threat of predation due to (1) adult avoidance of oviposition sites where predators are present (e.g., Resetarits and Wilbur 1989), (2) decreased larval foraging and, therefore, growth rates as a result of staying in refuges to avoid predators (e.g., Kiesecker 1997 and Kiesecker and Blaustein 1998), and (3) decreased adult foraging and growth rates as a result of avoiding areas with bullfrogs. Native amphibian larvae or adults may also be subject to chemically mediated interference competition (e.g., Petranka 1989 and Griffiths et al. 1993) or exploitative competition for resources (e.g., Kupferberg 1997). Finally, reptile predators that are dependent on larval or adult amphibians as a food source may also be impacted as a result of the loss of native amphibian larvae and the presence of larger bullfrog tadpoles and adults that they are unable to efficiently forage on (e.g., Kupferberg 1994).

Impacts of Nonindigenous Species as Vectors for Pathogens

Reports of mass mortality of amphibians due to pathogens are increasingly common (e.g., Nyman 1986, Worthylake and Hovingh 1989, Carey 1993, Blaustein et al. 1994b, Berger et al. 1998, and Lips 1999). Nonindigenous species, such as the bullfrog and centrarchid, percid, and salmonid fishes, may act as vectors for pathogens of herpetofauna. For example, *Saprolegnia*, a common pathogen of fish species reared and released from fish hatcheries, has recently been associated with declines of amphibian populations (Blaustein et al. 1994b). Releasing hatchery-raised fish may, therefore, increase the inoculation rate and lead to declines in native amphibian populations. Laurance et al. (1996) suggest that declines in stream-dwelling amphibian populations in Australia are caused by an unknown pathogen and hypothesize that nonindigenous species, such as the cane toad (*Bufo marinus*) and aquarium fish, are responsible for the introduction of the pathogen. Similarly, nonindigenous organisms may change environmental conditions leading to enhanced survival and number of pathogens. For example, Worthylake and Hovingh (1989) found that elevated nitrogen levels, caused by high numbers of sheep, increased bacterial concentrations and lead to periodic mass mortality of salamanders. Finally, pathogens may act synergistically with other natural and anthropogenically caused environmental stressors. For example, Kiesecker and Blaustein (1995) found that an interaction between UV-B radiation and *Saprolegnia* fungus enhanced the mortality of amphibian embryos.

Impacts of Weeds and Weed and Pest Management Activities

Noxious weeds may be spread by the use of off-road vehicles, watercraft, recreational livestock use, and camping activities. There is little knowledge of the impacts that weeds have on herpetofauna communities. However, nonindigenous aquatic and terrestrial weeds often form dense stands that are likely to exclude amphibian and reptile species that are sensitive to changes in microhabitat. For example, Germano and Hungerford (1981) and Scott (1996) report that lizards in the Sonoran Desert were sensitive to introduced grasses clogging their foraging, display, and escape pathways. Similarly, Reynolds (1979) found densities of sagebrush lizards and pygmy short-horned lizards were much lower in areas with introduced crested wheatgrass (*Agropyron cristatum*) than in areas with native big sagebrush (*Artemisia tridentata*) habitat on the Idaho National Engineering Laboratory. In addition to directly harming native species, the introduction of weed species may enhance the probability of successful introduction of other exotic species. For example, there is some evidence that the survival of exotic bullfrogs is enhanced by the presence of exotic aquatic vegetation, which provides habitat more suitable to the bullfrogs (Kupferberg 1996).

Management of weeds and insect pests with chemical herbicides and pesticides can have major impacts on herpetofauna communities. In particular, several features of amphibian biology may enhance their susceptibility to chemical contamination (Stebbins and Cohen 1995). The life history of most amphibians involves both aquatic larvae and terrestrial adults, allowing exposure to toxicants in both habitats. Many amphibians have skin with vascularization in the epidermis and little keritinization, allowing easy absorption of many toxicants. In fact, many studies have demonstrated the effects of chemical contamination on amphibians (reviewed in Cooke 1981, Hall and Henry 1992, Boyer and Grue 1995, and Carey and Bryant 1995). The effects range from direct mortality to sublethal effects such as depressed disease resistance, inhibition of growth and development, decreased reproductive ability, inhibition of predator avoidance behaviors, and morphological abnormalities.

Currently, there are no requirements for testing the toxicity of herbicides and pesticides on amphibians or reptiles (Hall and Henry 1992). Furthermore, there are no water quality criteria established for herpetofauna (Boyer and Grue 1995). It is often assumed that criteria for mammals, birds, and fish will incorporate the protection needed for amphibians and reptiles. The few chemicals that have been tested with fish and larval amphibians suggest that tadpoles may be more vulnerable to some toxicants than others (Hall and Henry 1992 and Boyer and Grue 1995). Several studies have examined the acute (lethal) toxicity of herbicides and pesticides on amphibians. Saunders (1970) and Harfenist et al. (1989) reviewed the effects of 25 and 211 different pollutants, respectively. However, it is important to recognize sublethal effects as well. Johnson and Prine (1976) found that organophosphates affect the thermal tolerance of western toad (*Bufo boreas*) tadpoles. Polychlorinated biphenyls (PCBs) and organochlorines can disrupt corticosterone production and inhibit glucogenesis (Gendron et al. 1997). Many pesticides result in decreased growth rate and inhibition of a predator response in amphibians (e.g., Berrill et al. 1993 and Berrill et al. 1994). Few studies have examined the effects of herbicides and pesticides on reptiles (Hall and Henry 1992). However, Hall and Clark (1982) found that *Anolis* lizards were at least as sensitive as birds and mammals to

organophosphates. Also, some (PCBs) and DDT are known to act as estrogens, resulting in skewed gender ratios and gonad abnormalities in turtles (Bergeron et al. 1994) and alligators (Guillette et al. 1994).

Many of the newer pesticides and herbicides are designed to decompose soon after application. Although still toxic, presumably this reduces the impact area and, thus, the number of exposed individuals. However, many of the older chemicals may still be present in sediments. For example, Russell et al. (1995) found potentially toxic levels of DDT in tissues of spring peepers (*Pseudacris crucifer*) at Point Pelee National Park, Ontario, even though DDT had not been used in the area for 26 years. Levels as high as 1,188 μg/kg of DDT were found in spring peepers and implicate DDT as a possible causative agent in the local extinction of several amphibian populations.

Guidelines Pertaining to Nonindigenous Species and Their Management

1. The impacts of introduced fish, bullfrogs, weeds, and pathogens on Montana's native amphibians and reptiles should be formally investigated.
2. Introduction of nonindigenous fish species should be limited to areas where they have already been introduced and nonindigenous fish should be removed from waters that act as key overwintering or breeding sites for amphibians.
3. Streams and lakes should be thoroughly surveyed for amphibians and turtles prior to and after the application of piscicides in order to identify impacts of piscicide application.
4. If lakes are to be treated with piscicides, they should be treated in late summer after most amphibian larvae have metamorphosed and before amphibians and turtles enter deeper water bodies for overwintering. When amphibians and turtles are present an effort should be made to remove them before treatments begin.
5. Piscicides should not be used in streams containing tailed frogs because of the possibility of removing multiple larval and adult cohorts. Other methods of removal should be explored in these instances. If piscicide use is the only option available then pretreatment gathering and posttreatment restocking of tailed frog tadpoles and adults should be undertaken and treatment should occur in the late evening hours so that adults are more likely to exit treated waters.
6. The public should be educated on the possible impacts of bullfrogs on native aquatic and terrestrial communities and be made aware of the fact that it is illegal to introduce them into the wild in Montana.
7. The impacts of commonly used herbicides and pesticides on Montana's herpetofauna should be formally investigated.
8. In the meantime herbicide and pesticide use should be limited to brands that rapidly decompose after application, and herbicides and pesticides should not be sprayed within 300 meters of water bodies or wetlands. Alternative methods of weed and pest removal should be used in these areas.

ROAD AND TRAIL DEVELOPMENT AND ON- AND OFF-ROAD VEHICLE USE

Background

Many recreational activities involve motorized use of roadways through public lands. Furthermore, off-road vehicle use is increasing in popularity and is extending the impacts of motorized traffic. Direct mortality from collisions with vehicles has been extensively documented for herpetofauna species. Several management options, from underpasses to road closures, may reduce such road kill. Although less studied, herpetofauna may also suffer from indirect impacts of motorized activities. Reduced habitat quality, habitat fragmentation, and vehicle noise may all be potentially important indirect impacts. In addition, many predators may use roads and trails to access sites with amphibian and reptile prey. Finally, several recreational activities may result in direct or indirect chemical contamination of herpetofauna habitat. For example, road, trail, or campground construction and off-road vehicle use can disturb soils laden with heavy metals or other toxicants leading to chemical contamination of waters.

Road Kill

Many studies have documented the large number of amphibians and reptiles that are killed on roadways (e.g., Campbell 1956, Van Gelder 1973, Dodd et al. 1989, Bernardino and Dalrymple 1992, Fahrig et al. 1995, and Rosen and Lowe 1994). For example, Rosen and Lowe (1994) estimated that 13.5 snakes/kilometer/year were killed on state highways in southern Arizona. Campbell (1956) estimated that between 10,000 and 25,000 snakes per year

were killed on roads in New Mexico in the early 1950's. Ehmann and Cogger (1985) estimated that five million reptiles and frogs are killed annually on Australian roads. One study has even documented motorist tendencies to swerve out of their way to ensure hitting snakes (Langley et al. 1989). However, snakes are not the only victims. Where U.S. Highway 93 intersects the Ninepipe National Wildlife Refuge in Montana, at least 205 western painted turtles (*Chrysemys picta bellii*) were killed along a 7.2 kilometer stretch of highway in a single field season (Fowle 1996). Many amphibians undergo mass migrations to and from breeding habitats and may be killed in the thousands while crossing roads (e.g., Koch and Peterson 1995 and Langton 1989).

Although the number of mortalities reported in road-kill studies is alarming, only a few studies have taken the extra step to demonstrate an impact of such mortality at the population level (e.g., Lehtinen et al. 1999). Population density of western painted turtles was positively associated with distance from U.S. Highway 93 in Montana (Fowle 1996). Similarly, Vos and Chardon (1998) found that the density of roads within 250 meters of a pond site was negatively associated with the size of moor frog (*Rana arvalis*) populations. Furthermore, the density of roads within 750 meters of a pond site was negatively associated with the probability that the pond would be occupied at all. In another study Van Gelder (1973) estimated that 30% of the females from a local breeding population of the common toad (*Bufo bufo*) succumbed to road kill and an equivalent percentage for males was likely. Finally, in a study of frogs and toads, Fahrig et al. (1995) found the proportion of dead-to-live animals increased and the total density of animals decreased with increasing traffic intensity.

Several management options are available to reduce traffic mortality on established roads including culverts or underpasses, temporary road closures during major migrations, reduced speed zones, or relocating roads (Langton 1989, Bush et al. 1991, Bernardino and Dalrymple 1992, Yanes et al. 1995, and Boarman and Sazaki 1996). Boarman and Sazaki (1996) found that drift fences and culverts effectively reduced road mortality for the threatened desert tortoise (*Gopherus agassizii*). Spotted salamanders (*Ambystoma maculatum*) also appear to successfully use culverts (Jackson and Tyning 1989). However, Auiderwijk (1989) reported that less than 4% of a local toad population used culverts installed for their migration. Yanes et al. (1995) suggest that culvert dimensions, road width, height of drift fence, and vegetation along roadways may all influence the effectiveness of culverts. Funnels leading into culverts, vegetation around culvert openings and pitfall-trap entrances may all enhance the effectiveness of culverts. Many other suggestions for constructing effective culverts can be found in the studies reported by Langton (1989).

Off-Road Vehicle Impacts

The impacts of motorized vehicles on amphibian and reptile populations do not end at the roadside. Although far less studied, impacts from ORVs have been documented. In addition to direct mortality resulting from collisions, ORVs may disrupt habitat to the point that it becomes unusable by herpetofauna. Busack and Bury (1974) established 3 plots, each 1 hectare in size, in areas where the vegetation had been heavily damaged by ORVs, moderately damaged by ORVs and little damaged by ORVs. Of 4 lizard species found in the area, 2 specimens were captured in the heavily damaged site compared to 15 and 24 in the moderately and little damaged sites respectively. In a similar study, Bury et al. (1977) established replicate plots arranged into 4 ORV-use categories; control, moderate, heavy and "pit areas" (the latter are concentrated-use areas). Eight reptile species were captured during 3 days of sampling, and the total number of individuals differed between the plot types. Moderate use, heavy use, and pit areas had 31%, 72%, and 85% fewer reptiles respectively than the control plots. The study also found that numbers of birds and mammals, potential prey for some herpetofauna, were reduced in ORV-use areas.

Noise from on- and off-road vehicles is also likely to have negative indirect impacts on herpetofauna. For example, Nash et al. (1970) found that leopard frogs exposed to loud noises (120 decibels) remained immobilized for much longer periods of time than a similarly handled control group. Thus, an immobility reaction resulting from noise-induced fear could increase mortality of herpetofauna that inhabit areas used by ORVs or for herpetofauna undertaking road crossings by inhibiting their ability to find shelter or move across a roadway. Similarly, studies in the Sonoran Desert found that motorcycle and dune buggy sounds ($\geq$ 100 decibels) decreased the acoustical sensitivities of a number of lizard species (Bondello 1976 and Brattstrom and Bondello 1979). Some species were particularly sensitive to these sounds and exposures as short as 8 minutes in duration resulted in actual hearing loss (Brattstrom and Bondello 1979). Thus, vehicle noise may indirectly cause mortality by eliminating the species' ability to detect and capture necessary food items and detect and avoid predators. Although we found no studies documenting the impacts of noise on breeding choruses of amphibians, it is also possible that vehicle noise may not

allow amphibians to properly hear and move toward breeding aggregations. This may be especially true for species such as our native Columbia spotted frog (*Rana luteiventris*) and boreal toad, which do not have loud calls and may not be heard from long distances or in the presence of other noises.

Chemical Contamination and Sedimentation from Roads

Soil disturbance has been directly implicated in both lethal and sublethal effects on amphibians. If not contained, road construction may cause increased sedimentation in adjoining aquatic habitats. Road construction in Redwood National Park introduced large amounts of sediments into neighboring streams and densities of tailed frogs, Pacific giant salamanders (*Dicamptodon tenebrosus*), and southern torrent salamanders (*Rhyacotriton variegatus*) were lower in these streams compared to nearby control streams (Welsh and Ollivier 1998). The impacts of sedimentation may be further heightened if the sediments contain toxic materials. Road construction in Great Smoky Mountains National Park involved using fill from the Anakeestra rock formation that, when oxidized, formed a leachate with sulfuric acid, iron, zinc, manganese, and aluminum (Huckabee et al. 1975, Kucken et al. 1994). Runoff from roadsides and culverts resulted in contamination of streams within the park and 2 stream breeding salamander species were eliminated and 2 other species exhibited a 50% reduction in population size. Declines in macroinvertebrates and fish were also noted. Similarly, disturbance of, and runoff from, mine tailings increased the acidity and heavy metal concentrations in a drainage system in Colorado (Porter and Hakanson 1976). Laboratory bioassays indicated that water in the drainage was lethal for western toad larvae and required a 1000 fold dilution before tadpoles were able to survive. Sublethal effects may also result from heavy metal poisoning (e.g., Lefcort et al. 1998). Deformities in the oral cavity were observed in bullfrog tadpoles exposed to sediments high in arsenic, barium, cadmium, chromium, and selenium (Rowe et al. 1998), and southern toads (*Bufo terrestris*) exposed to coal combustion wastes had elevated levels of stress hormones (Hopkins et al. 1997).

Contaminated runoff from roads or campground surfaces may also affect amphibians. Lead concentrations in frog tadpoles living in roadside ponds and ditches were correlated with daily traffic volumes in Maryland and Virginia (Birdsall et al. 1986). Concentrations as high as 270 mg/kg were discovered; levels that are associated with decreased reproduction and growth. Petroleum products may also contaminate aquatic habitats next to roadways or may be directly introduced from motorized watercraft. Mahaney (1994) examined the effects of crankcase oil on tadpoles of the green treefrog (*Hyla cinerea*). Concentrations of 100 mg/L inhibited tadpole growth and prevented metamorphosis.

Guidelines Pertaining to Road and Trail Development and On- and Off-Road Vehicle Use

1. The impacts of road and trail development, on- and off-road vehicle use, and watercraft use on Montana's herpetofauna should be formally studied, especially in areas of high human use.
2. Potential road and trail routes should be thoroughly surveyed for amphibians and reptiles in order to identify impacts of road or trail construction and vehicle use.
3. When possible roads and trails should avoid water bodies, wetlands, and denning sites that are key habitats for amphibians and reptiles.
4. When new roads and trails must be constructed near water bodies or wetlands care should be taken to avoid increased sedimentation, maintain the essential hydrographic period, and allow natural processes, such as changes in river courses to continue.
5. Areas identified as key migration routes should either be closed to vehicle use during peak migration periods or culverts and underpasses should be constructed in conjunction with drift fences in order to minimize road mortality.
6. ORV use should be restricted to designated roads, trails, or pit areas.
7. Road and trail development and off-road vehicle use in areas with soils that contain mine tailings or other toxic substances should be prevented. If road and trail construction is absolutely necessary in these areas then reclamation activities should be undertaken prior to road or trail construction.

DEVELOPMENT AND MANAGEMENT OF WATER IMPOUNDMENTS AND RECREATIONAL FACILITIES

Background

The development of recreational facilities, including the development of water impoundments, may result in the loss of key breeding, foraging, and overwintering habitats for herpetofauna. Recreational facilities also often bring people and their pets into direct contact with native wildlife and, in some cases, herpetofauna may be negatively impacted by this contact. In addition, recreational facilities may also have negative impacts on herpetofauna through artificial lighting sources, which may alter their behavior, and by subsidizing native predators, which may survive at artificially high numbers through the use of human resources while continuing to prey on native herpetofauna.

Impacts from Water Impoundments

Water impoundments provide a variety of recreational opportunities including fishing, hunting, swimming, boating, and camping. In some cases these water impoundments may create breeding, foraging, and overwintering habitat for herpetofauna in areas that were previously inhospitable (Cooper et al. 1998). However, in a number instances, the development of water impoundments can result in the loss of key breeding, overwintering, and foraging habitats for herpetofauna. For example, development of a series of water impoundments along the Colorado River in Texas extirpated the Concho water snake (*Nerodia harteri paucimaculata*), a species that depends on riffle habitats, from much of its historic range, eventually leading to its federal listing as an endangered species (Mathews 1989). Similarly, the construction of Jordanelle Reservoir on the Provo River in Utah flooded a large amount of habitat used by Columbia spotted frogs, a species that is threatened in the region (Wilkinson 1996a). Water impoundments can also cause downstream riverine habitats to deteriorate as a result of changes in flow regimes. Lind et al. (1996) found that reduced water flows below dams on the Trinity River in California resulted in the loss of flood plain breeding pools and vegetational overgrowth of riparian areas used for basking and foraging by amphibians.

Furthermore, manipulation of water levels in water impoundments can result in direct and indirect mortality of amphibian larvae and eggs. For example, during the summer of 1998, fluctuating water levels in Cabinet Gorge Reservoir in northwest Montana led to the desiccation of Columbia spotted frog eggs and larvae when water levels dropped for power generation (Bryce Maxell, personal observation). Fluctuations in water levels may also cause a decline in water temperatures as a result of increased water movement. Colder water temperatures may increase mortality by decreasing larval growth rates and increasing the length of the larval life history stage (Wilbur 1980). Colder water temperatures can also result in a decreased immune response, leaving amphibian larvae more susceptible to pathogens (Nyman 1986, Carey 1993, and Maniero and Carey 1997). Some factors associated with water level fluctuations may interact in a complex manner resulting in amphibian mortality. For example, Worthylake and Hovingh (1989) describe periodic mass mortality of tiger salamanders (*Ambystoma tigrinum*) caused by interactions between fluctuating water levels, high numbers of sheep, and high levels of a pathogenic bacteria (*Acinetobacter* spp.). High numbers of sheep increased the nitrogen input into the lake and, combined with low water levels, resulted in high nitrogen concentrations that were conducive to the pathogen. Kiesecker and Blaustein (1997a) describe another complex interaction. Western toads apparently lay their eggs in one particular portion of an Oregon lake, regardless of the water levels. Low water levels resulted in mass mortality of toad eggs due to the synergistic effect of UV-B radiation and the pathogenic fungus *Saprolegnia*. Moving eggs to deeper waters significantly reduced egg mortality.

Some water impoundments are managed exclusively for waterfowl production. Because many waterfowl and wading birds feed on amphibians and reptiles (Duellman and Trueb 1986), concentrated numbers of waterfowl may lead to increased depredation. Furthermore, high concentrations of migratory waterfowl have been associated with decreased water quality (Manny et al. 1994 and Post et al. 1998) and habitat degradation (Kerbes et al. 1990 and Ankney 1996). For example, Post et al. (1998) estimated that waterfowl increased nitrogen and phosphorus levels by 40% and 75%, respectively, on Bosque del Apache National Wildlife Refuge in the winter of 1995-1996, and Kerbes et al. (1990) reported that high concentrations of snow geese (*Chen caerulescens*) have lead to destruction of wetland vegetation.

Finally, although many of the negative impacts associated with water impoundments mentioned above are associated with amphibians, declines in amphibian populations resulting from water impoundments would also be expected to lead to declines in reptile predators that depend on amphibians as prey (Kupferberg 1994 and Koch et al. 1996).

Recreational Facilities

Several aspects of recreational facilities and associated activities may negatively impact herpetofauna. For example, Garber and Burger (1995) documented the decline in populations of wood turtle (*Clemmys insculpta*) during a 10-year time period as the result of a New England wildlife reserve being opened up to human recreation. Recreationists were required to obtain permits to use the reserve, and the rate of turtle declines was highly correlated with the number of permits issued each year, apparently as a result of removal by recreationists.

Amphibian and reptile populations in or near recreational facilities may be at risk of increased mortality as a result of handling and killing by humans. Herpetofauna may become stressed by human handling (e.g., Reinking et al. 1980) and, if translocated to unfamiliar microhabitats, may not be able to find local refugia from predators, or water to rehydrate themselves. Furthermore, people may intentionally kill herpetofauna that they feel threatened by, especially rattlesnakes and bullsnakes (*Pituophis catenifer*), which may be confused for rattlesnakes by people unfamiliar with their identification. This is unfortunate because all snakes in Montana, with the exception of the prairie rattlesnake (*Crotalus viridis viridis*), are nonvenomous, and all herpetofauna in Montana, including the prairie rattlesnake, pose little threat to human safety (Reichel and Flath 1995). Fewer than 2,000 people are bitten by venomous snakes each year in the United States and fewer than 10 of these incidents result in death; the chances that someone will be killed by lightning are greater than their chances of dying as a result of snakebite (Reichel and Flath 1995 and Greene 1997). Several recent studies support the idea that from the perspective of a relatively small snake that would never consider humans as food items and could easily be injured by them, it makes sense to: (1) avoid being detected by remaining concealed or fleeing, (2) if detected and threatened, bluff an attack, and (3) if the bluff does not work, bite as a last line of defense. For example, Prior and Weatherhead (1994) found that in 174 trials in which eastern Massasauga rattlesnakes (*Sistrurus catenatus*) were approached to within 0.5 meters or less the snake did not strike; snakes only bit when physically restrained. Similarly, Gibbons and Dorcas (1998) found that only 10% of the cottonmouths (*Agkistrodon piscivorus*) they intentionally stepped on while wearing snake-proof boots would bite the boot and only 40% of snakes picked up by glove-covered snake tongs would bite the glove.

Amphibian and reptile populations in or near recreational facilities may also face increased mortality as a result of handling and killing by human pets, stray dogs and cats, and a number of wild predators that are supported in larger numbers around areas of human activity. For example, domestic dogs and cats introduced to islands in the West Indies nearly extirpated a population of rock iguanas (*Cyclura carinata*) (Iverson 1978) and feral cats in Victoria, Australia commonly fed on frogs and lizards (Coman and Brunner 1972). In the United States there may be more than 120 million dogs and cats, with as many as 50 million of these being homeless (Denney 1974). The impact these dogs and cats have on herpetofauna populations is largely unknown. However, snakes and lizards were a common food item in the diets of feral cats in Oklahoma and Texas (McMurry and Sperry 1941 and Parmalee 1953) and it is possible that some herpetofauna populations in Montana could be impacted as well. Wild predators, including ravens (*Corvus corax*), striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), coyotes (*Canis latrans*), and foxes (*Vulpes vulpes*) may be supported at artificially high numbers around areas of human activity due to the availability of human refuse and a lack of larger predators. Olson (1989) found that ravens depredated more than 20% of a breeding aggregation of western toads in the Oregon Cascades. Similarly, Schaaf and Garton (1970) found that raccoons ate at least 50 individuals of a breeding chorus of American toads (*Bufo americanus*) and Christiansen and Gallaway (1984) found that predation of turtle nests was significantly higher in the presence of raccoons. In the Lee Metcalf National Wildlife Refuge in Montana, Corn and Hendricks (1998) found 75% of western painted turtle nests were destroyed by predators within 30 days of egg laying; based on tracks likely predators included skunks, coyotes, and raccoons.

Finally, a number of amphibians and reptiles breed and forage nocturnally and it is possible that artificial lighting at recreational facilities may negatively impact these activities. For example, large choruses of breeding Pacific treefrogs (*Hyla regilla*) in western Montana can be rapidly and completely quieted by shining a flashlight across a breeding pond, and calling may not be reinitiated for up to 5 minutes (Bryce Maxell, personal observation). If

breeding ponds are subject to constant illumination by a fixed light or repeated exposure to car lights near a recreational facility it is possible that breeding success may be negatively impacted. Similarly, nocturnal foraging behavior of amphibians and reptiles may be impacted by the presence of artificial lights, especially when species depend on extremely dark conditions (e.g., Hailman 1982). Buchanan (1993) found that the ability of nocturnally foraging grey treefrogs (*Hyla versicolor*) to detect and subsequently consume prey was significantly reduced when artificial light sources were present as compared to ambient-light conditions. It would also be expected that nocturnally foraging snakes that depend on concealment from prey, which they recognize by olfactory cues, might have reduced foraging success in the presence of artificial light sources.

Guidelines Pertaining to Development and Management of Water Impoundments and Recreational Facilities

1. The impact of recreational facilities, water impoundments, and associated human activities on amphibian and reptile populations should be formally investigated.
2. Current and potential sites for recreational facilities and water impoundments should be thoroughly surveyed for amphibians and reptiles in order to identify potential impacts of these facilities on native species.
3. New recreational facilities should not be located within 300 meters of key breeding, foraging, or overwintering habitats.
4. When past or future water impoundments have eliminated key breeding, foraging, and overwintering habitats, impacts on amphibians should be mitigated by the creation of adjacent wetlands that have areas with deeper waters for overwintering and areas with shallow waters for larval rearing. Furthermore, fish should not be introduced to these water bodies and fluctuations in water levels at these sites should not be correlated with fluctuations in water levels in the adjacent water impoundment.
5. Downstream flows from water impoundments should mimic natural flow regimes in order to maintain flood plain breeding and foraging habitats.
6. Management of habitats exclusively for waterfowl production should be avoided. A multispecies or community approach is preferable.
7. Recreational facilities located near documented populations of amphibians and reptiles should contain educational signs or pamphlets pertaining to the amphibians and reptiles in the area and how humans and their pets may impact them. At recreational sites where rattlesnakes may be encountered information on reducing the risks of being bitten and emergency treatment for bites should be presented.
8. If domestic or wild predators are found in areas, such as key breeding or nesting habitat where native herpetofauna would naturally occur in high densities, predator control programs may be required in order to ensure that native herpetofauna communities will persist.
9. The subsidization of native predators should be minimized by maintaining fully enclosed waste facilities.

HARVEST AND COMMERCE

Impacts of Harvesting, Collecting, and Commerce

The worldwide collection and harvest of amphibians and reptiles for food, sport, and commerce as pets, skins, art, souvenirs, and medicinal products is extensive. Hundreds of millions of herpetofauna are removed from the wild and/or killed each year for these activities and annual worldwide commerce in herpetofauna may be valued in the hundreds of millions, perhaps even billions, of dollars (e.g., Wilkinson 1996b, Buck 1997, and Pough et al. 1998).

Unfortunately, we currently do not know the degree to which Montana's amphibians and reptiles are collected or harvested for biological or commercial purposes. However, it may be quite substantial based on the few observations and records we do have. The Montana Fish, Wildlife and Parks receives regular requests regarding permits for collecting amphibians and reptiles in Montana (Dennis Flath, Montana Fish, Wildlife, and Parks, personal communication). It would be expected that these collectors may be targeting rarer herpetofauna such as the Coeur d' Alene salamander (*Plethodon idahoensis*), short-horned lizard, western hognose snake, smooth green snake, and milk snake that are desired in the pet trade. However, most of the records we have for commercial collecting of herpetofauna in Montana are for the collecting of prairie rattlesnakes. For example, in the Fall of 1998, Montana Fish, Wildlife, and Parks was contacted by the Arizona Department of Fish and Game after they had stopped a man at a game check station with several hundred pounds of frozen rattlesnakes that he had collected in

Montana (Dennis Flath, Montana Fish, Wildlife, and Parks, personal communication). Furthermore, the scientific and public literature is full of references to prairie rattlesnakes that were collected in Montana. The author of an article in *Montana Wildlife* claims to have captured and killed 5,000 rattlesnakes in Beaverhead County, Montana during a 20-year period in which he also shipped many live snakes to zoos and sportsmen's clubs across the United States (Sweet 1953). In an article on some rattlesnakes that were shipped to him, Gloyd (1933) reports hundreds of rattlesnakes being killed at the point of collection, an apparent den site, near Sunburst, Montana. In another example, Dean et al. (1980) report receiving specimens from a commercial collector, the Montana Rattlesnake Company, based in Wilsall, Montana, which collected 23 gravid female rattlesnakes from the Missouri Breaks region of northern Montana.

Fortunately, there is no evidence that rattlesnake roundups have become a popular public event in Montana the way they have in more southern states (e.g., Black 1981, Clark 1991, and Weir 1992). These events can result in the collection of thousands of rattlesnakes, which are often subjected to inhumane treatments such as having gasoline or other chemicals poured into their dens to facilitate collection, allowing snakes to dehydrate or starve, suffocating snakes in "snake pits", pulling rattles off of live individuals, amputating tails of live individuals, and burning individuals alive (Clark 1991). Rattlesnake roundups may also result in the collection and killing of other herpetofauna species and the destruction of microhabitats, permanent shelters, and hibernacula used by a variety of herpetofauna (Campbell et al. 1989, and Warwick 1990).

Montana's 2 rarest species of turtles, the common snapping turtle and spiny softshell turtle, may also be the target of frequent harvest for human consumption because of the large body size attained by some adults. Unfortunately, populations of these turtles may be severely impacted by the harvest of larger sexually mature adults because the majority of turtles do not survive to sexual maturity (which may not be reached until the age of 16), and adults that do survive may produce offspring for decades (Congdon et al. 1993, and Congdon et al. 1994). Congdon et al. (1994) found that only a 10% increase in annual mortality of adult common snapping turtles over 15 years of age would halve the number of adults in less than 20 years.

Guidelines Pertaining to Harvest and Commerce

1. The degree to which amphibians and reptiles are harvested in Montana and the impacts of harvesting on populations of amphibians and reptiles should be formally studied.
2. Statutes that require permits for collecting or harvesting amphibians and reptiles should be clarified and updated.
3. Collecting or harvesting rare species such as the Coeur d' Alene salamander, common snapping turtle, spiny softshell turtle, short-horned lizard, western hognose snake, smooth green snake, and milk snake, which may be desired by the pet trade or for human consumption, should be prohibited in order to prevent declines in these species.
4. Rattlesnake roundups, as public events, should be prohibited.
5. A public education program should be undertaken in order to encourage people to enjoy and value amphibians and reptiles in the wild.

HABITAT LOSS AND METAPOPULATION IMPACTS

Many of the recreational activities described in this chapter, and anthropogenic impacts in general, may result in the loss and/or fragmentation of herpetofauna habitat. Roads, trails, ORV use, recreational facilities, and water impoundments can replace natural habitat, and this destruction can obviously displace herpetofauna populations (e.g., Bury et al. 1980, Dodd 1990, Lind et al. 1996, and Beebee 1997). Similarly, nonindigenous species, including fish and bullfrogs, can extirpate local populations of native herpetofauna (e.g., Rosen et al. 1995 and Knapp 1996). Loss of individual local populations may also influence the persistence of regional populations (generally referred to as metapopulations) even when the total amount of habitat remains constant (e.g., Hanski and Gilpin 1991, Robinson et al. 1992, Simberloff 1993, Fahrig and Merriam 1994, and Margules et al. 1994). For example, Rosen et al. (1995) found that extirpation of native amphibians in Arizona resulting from the introduction of nonindigenous bullfrogs and fishes into permanent water bodies also led to the extirpation of native amphibians from nearby regions when the smaller water bodies that the natives had been exiled to dried up during a drought. Thus, loss of core habitats that support local source populations can lead to more widespread extirpations.

Habitat patch size, shape, isolation, and quality all influence the persistence of regional collections of populations or metapopulations. The size of habitat patches is often associated with the probability that a patch is occupied by amphibian or reptile species (e.g., Laan and Verboom 1990, Branch et al. 1996, Marsh and Pearman 1997, Fahrig 1998, and Hokit et al. 1999). Patch distribution across a landscape may also greatly influence whether a patch is occupied or not. The degree of patch isolation is often negatively associated with patch occupancy (Sjögren 1991, Vos and Stumpel 1995, Branch et al. 1996, Sjögren-Gulve and Ray 1996, and Hokit et al. 1999). Even manipulating the matrix habitat in between habitat patches can influence patch occupancy. For example, Sjögren-Gulve and Ray (1996) found that ditches meant to drain forest areas between frog ponds effectively isolated them even though the distance between ponds had not been altered.

Another complication is that different species respond to patchy landscapes in different ways. The dispersal abilities of a species, both the distance it moves and its ability to move through matrix habitat, can greatly affect patch occupancy patterns. For example, Florida scrub lizards (*Sceloporus woodi*) and six-lined racerunners (*Cnemidophorus sexlineatus*) are similar in body size and habitat preferences, but the relatively low vagility of scrub lizards resulted in a restricted distribution across the same landscape of scrub habitat patches (Hokit et al. 1999). The different dispersal abilities of herpetofauna species can cause difficulty in defining a habitat patch and dispersal buffers around patches. Semlitsch (1998) found that six species of *Ambystoma* salamanders varied in their dispersal and use of habitat surrounding ponds. Some species dispersed and used terrestrial habitat up to 250 meters from the pond edge, suggesting that managers need to seriously consider providing extensive buffer zones surrounding water bodies and wetlands. Species may also differ with respect to their response to habitat edges. For instance, Demaynadier and Hunter (1998) found that while salamanders, frogs, and toads were all negatively effected by forest edges, salamanders were much more sensitive to abrupt forest edges than frogs and toads. On the other hand, northern alligator lizards (*Elgaria coerulea*) in Montana are positively affected by forest edges and may have increased rates of dispersal as a result of road cuts or forest clearcuts (Hart et al. 1998).

Guidelines Pertaining to Habitat Fragmentation

1. The effects of habitat fragmentation should be formally investigated for all amphibian and reptile species in Montana. Specifically, the degree to which each species tolerates habitat fragmentation should be identified.
2. Loss or deterioration of overwintering, breeding, foraging, or migration habitats used by various amphibian and reptile species should be avoided.
3. When loss or deterioration of overwintering, breeding, foraging, or migration habitat is unavoidable, mitigation measures should be addressed in order to ensure that regional populations of amphibians and reptiles are maintained.

OVERALL CONCLUSIONS

The relatively poor knowledge we have of the distribution, biology, and status of many of Montana's herpetofauna highlights the need to undertake thorough inventories of our public lands. Furthermore, the lack of knowledge of the distribution and status of many of these species makes it all the more important to properly manage recreational and travel activities that may impact them. This point is highlighted by the findings of Hart et al. (1998) and Redmond et al. (1998), which show that herpetofauna are relatively less protected by public lands than other terrestrial vertebrates in Montana. These findings emphasize the dual necessities of (1) properly protecting herpetofauna species on our public lands and (2) properly educating citizens so that they can appreciate herpetofauna and have a stake in protecting them on private lands, which herpetofauna largely depend on for survival.

Although recreational impacts on Montana herpetofauna have been little studied, the literature provides several examples of factors often associated with recreation that do affect amphibian and reptile populations. Nonindigenous species can directly affect herpetofauna via competition and predation, and management of nonindigenous species can indirectly affect herpetofauna as well. For example, piscicides, herbicides, and pesticides are known to impact amphibian populations. Road traffic and off-road vehicle use directly kill herpetofauna and

indirectly impact populations by creating migration barriers, destroying habitats, and increasing chemical contamination and sedimentation. The development of recreational facilities and water impoundments may result in the loss of key breeding, foraging, and overwintering habitats for herpetofauna. Harvesting and collecting can have obvious impacts on herpetofauna populations and habitat loss may lead to fragmentation and disruption of metapopulation dynamics.

OVERALL GUIDELINES/RECOMMENDATIONS

Although we currently lack detailed knowledge of specific habitat requirements for many of Montana's herpetofauna as well as the impacts of various recreational and travel activities, this lack of knowledge should not deter us from making common sense decisions that are likely to provide protection to herpetofauna populations. Overall guidelines for recreational and travel activities follow and are based on our interpretation and synthesis of the available literature.

1. Thorough inventories of all state and federal lands should be conducted in order to determine the distribution and status of herpetofauna.
2. A statewide monitoring program should be established (similar to the breeding-bird survey) in which populations of herpetofauna near and away from human impacts are annually surveyed with calling surveys, egg and larval surveys, and pitfall and funnel trap surveys. Permanent sites should be chosen for year-to-year comparisons based on the presence of rarer species. If one person from each U.S. Forest Service district, Bureau of Land Management region, or Montana Fish, Wildlife and Parks region conducted 4-5 days of surveys each year, it would greatly increase our understanding of the status of herpetofauna populations and our ability to detect declines.
3. All state and federal field biologists should be trained in the identification of Montana's herpetofauna species. Biologists could be trained to identify all of the state's herpetofauna in a single, half-day training session.
4. All state and federal agencies should encourage personnel to report all incidental sightings of herpetofauna to the Montana Natural Heritage Program.
5. Formal research should be undertaken to identify the impacts of nonindigenous species, piscicides, pathogens, water impoundments, recreational facilities, habitat fragmentation, roads, and on- and off-road vehicles and watercraft on all of Montana's herpetofauna.
6. When possible, new recreational facilities or road and trail projects should not be constructed within 300 meters of key breeding, overwintering, or foraging sites. New water impoundments should not be constructed where they would flood key habitats.
7. Off-road vehicle use should be restricted to designated trails or play areas.
8. When unavoidable, impacts of recreation and travel activities should be mitigated by the creation of new habitat. New road projects should mitigate impacts to migrating herpetofauna by conducting surveys prior to construction and placing bridges or drift fence/tunnel systems in areas that intersect key migration routes.
9. Introduction of nonindigenous fish species and bullfrogs should be limited to areas where they have already been introduced, and fish and bullfrogs should be removed from sites that act as key overwintering or breeding sites for native herpetofauna.
10. Use of piscicides for fish removal should consider impacts on amphibians and aquatic reptiles and should be mitigated by conducting the removal in the fall after amphibian larvae have metamorphosed and before aquatic herpetofauna have moved to overwintering sites. Catching and holding herpetofauna in treated areas until piscicide levels have declined may be necessary.
11. Application of herbicides and pesticides should be excluded from within 300 meters of wetlands that act as key breeding, foraging, or overwintering habitats.
12. Educational programs on herpetofauna should be established, including the development of signs, posters, and outreach programs to schools.
13. Collecting permits for scientific research, harvest, and commerce should be required in order to track these activities and control their impacts on herpetofauna populations. Laws should be enacted that limit the taking of Montana's herpetofauna for the pet trade.
14. The management status of all herpetofauna on U.S. Forest Service and Bureau of Land Management lands should be reviewed.

INFORMATION NEEDS

Informational needs on Montana's herpetofauna are extensive. There is a lack of information on species' distributions within the state and, in many cases, basic life history traits are unknown. Recreation and travel impacts on herpetofauna in general and specifically here in Montana, have been little studied. The following is a list of some of the information that is most needed.

1. Accurate and extensive distribution data on all species known to inhabit the state.
2. Determination of whether or not the following species are present in the state:
    Idaho Giant Salamander (*Dicamptodon aterrimus*)
    Canadian Toad (*Bufo hemiophrys*)
    Wood Frog (*Rana sylvatica*)
    Great Basin Spadefoot (*Scaphiopus intermontanas*)
    Pygmy Short-horned Lizard (*Phrynosoma douglasi*)
3. Understanding the status of all species in the state through long-term monitoring.
4. Ecology, phenology, and life history data on all species in the state.
5. Impacts of nonindigenous fishes.
6. Impacts of various piscicides used in fisheries management.
7. Distribution and effects of the exotic bullfrog (*Rana catesbeiana*).
8. Information on the presence, spread, and impacts of various pathogens.
9. Extent of road mortality for all species.
10. Extent of ORV and watercraft induced mortality.
11. Impacts of various road building and maintenance activities.
12. Impacts of water impoundments and recreational facilities.
13. Extent of commercial and recreational collecting and harvest of all species.
14. Degree and effects of contamination of waters with herbicides, pesticides, fuels, and other chemicals.
15. Extent of mortality resulting from domestic, feral, and wild animals.
16. Impacts of waterfowl and waterfowl management activities.
17. Effects of anthropogenic sources of noise and light.
18. Degree and effects of habitat fragmentation for various species.
19. Identification of mitigation techniques for all of the anthropogenic impacts mentioned.